### B-4.4.1 Wind Blown Sediments

Wind blown sediments that overlay lava flows are a common soilscape at the INEEL. These soils range in texture from the fine-grained wind-blown glacial loess left behind by retreating glaciers during the Pleistocene epoch to eolian sand believed to have originated from the Big Lost and Snake Rivers and from the shorelines of the ancient Lake Terreton. Dating of the loess with thermoluminescence and radiocarbon methods indicates that at least two distinct episodes of loess accumulation are represented on the INEEL. The youngest loess was deposited between 10,000 and 40,000 years ago, and the older loess was deposited about 60,000 to 80,000 years ago (Forman et al. 1993). Soils developed in the two deposits are markedly distinct. Subsoil in the younger soil contains high amounts of carbonates that have accumulated over the years of low rainfall and high evaporation. In contrast, the older soil (paleosol) was developed when effective precipitation was higher. Consequently, salts have been leached out of the subsoil, and fine particles (clays) have been deposited from the surface to the subsoil. Subsoil horizons of the older soil have relatively high amounts of clay rather than carbonates.

### B-4.4.2 Alluvial Deposits

Deposits transported by rivers can be found in the flat expanses of the Big Lost River, Little Lost River, and Birch Creek alluvial plains. River action has truncated the former undulating lava landscape, leaving behind a layer of rounded river rock beneath a blanket of silty and sandy sediments.

The Big Lost River drains about 3,626 $km^2$ (1,400 $mi^2$). It enters the INEEL site on the southwest end, flows east, then flows northward, and terminates in the Big Lost River Sinks. Three recognized terraces of the Big Lost River are located on the INEEL. Around the TRA, older deposits are capped with desert pavement and present accumulated salts in the subsurface at a depth of about 25.4 to 30.5 cm (10 to 12 in.). Typically, the soils are gravelly sands to gravelly loams or loamy sands, with low water-holding capacity and high permeability. Younger deposits generally do not exhibit a well-developed carbonate-enriched subsurface horizon, and most are not capped with desert pavement.

Birch Creek originates from springs below Gilmore Summit in the Beaverhead Mountains and terminates on the INEEL in an area called the Birch Creek playa (a desert lake basin). The Birch Creek alluvial deposits on the INEEL are generally gravelly loams. The playa deposit, in contrast, is deep, calcareous, alkaline, silty clay loam or silty clay.

Alluvial plains offer flat terrain, subsurface gravels that are relatively easy to excavate, increased moisture and associated higher soil productivity, and desirable animal habitat. Most of the facilities at the INEEL have been located within alluvial plains. Gravel pits on the north end of the INEEL site are located within the cobbles and gravels deposited by Birch Creek. Near the CFA, several gravel pits are located within the deposits of the Big Lost River. Some of the pits are located at a considerable distance from the modern channel and mark the extent of the river during the glacial Pleistocene epoch.

### B-4.4.3 Lacustrine Deposits, Playas and Sand Dunes

The playa is another major landscape feature on the INEEL. The modern-day playas at the INEEL are the Birch Creek Playa and the Big Lost River sinks. These basins, located at the terminuses of the Big Lost River and Birch Creek, contain a thick layer of fine-grained sediments. Principal exposures of ancestral Lake Terreton occur in a lowland belt that trends eastward across the northern portion of the INEEL (Nace et al. 1975). This ancient lake encompasses the Birch Creek playa, as evidenced by lake-bed sediments beneath Birch Creek Playa sediment (Nace et al. 1975), and was probably fed by both the Big Lost River and Birch Creek. The ancestral lake bed is overlain in many areas by sand dunes or elongated sand "trains." The lacustrine deposits generally consist of clayey, alkaline surface soils over stratified subsoils. Some of the "slick spots" soils in the ancestral lakebed contain high amounts of exchangeable sodium and are characterized by a lack of vegetation and cracked surfaces. The deposits near TAN are generally quite saline and support a variety of salt-tolerant plant species.

Patches of sand throughout the ancestral lake area overlay the clayey lake deposits and are believed to have originated from the beaches of Lake Terreton or the Big Lost River or the Snake River. The sands on the northeast end of the INEEL Site are deposited in elongated dunes, which are likely still shifting like the St. Anthony Sand Dunes, and may have similar origins. The sand deposits typically support big sagebrush and Indian ricegrass, thus offering comparably tall, unique habitats.

Another set of significant playas on the INEEL is the spreading areas located on the southern end of the site, near the RWMC. The spreading areas also contain silty and clayey sediments of various depths.

### B-4.4.4 Colluvial Deposits

Colluvial deposits are prevalent along the base of the mountainous slopes on the west side of the INEEL and surrounding the East and Middle Buttes. Generally, the soils in these deposits are gravelly. Very little information is available about the soils within these deposits, except that these soils are subject to erosion, have comparably short growing seasons, and are generally suitable for rangelands and wildlife.

## B-5. SURFACE WATER HYDROLOGY

The INEEL is located within the Pioneer Basin, a closed surface drainage basin on the western boundary of the Eastern Snake River Plain. Natural surface water near or on the INEEL consists of three streams draining intermountain valleys to the north and northwest of the Site: the Big Lost River, Birch Creek, and the Little Lost River (Figure B-4). All of the streams are intermittent on the INEEL, with the Big Lost River having the highest flows entering the INEEL, Birch Creek having flows less than one quarter of the Big Lost River flows, while the Little Lost River does not flow onto the INEEL (DOE 1991). Stream flows are often depleted before reaching the INEEL by irrigation and hydropower diversions as well as infiltration losses along the channel beds. Surface water flows on the INEEL either infiltrate into the ground or evaporate.

The Big Lost River is the major surface water feature on the INEEL. Its waters drain the northeastern portion of the Pioneer Range and southwestern portion of the Little Lost River Range (Figure B-4). The upper reaches are impounded and regulated by Mackay Dam, located approximately 50 km (31 mi) northwest of Arco, Idaho. The Big Lost River flows from the dam southeastward through the Big Lost River valley, past Arco, and onto the ESRP. Stream flows are generally reduced before reaching the INEEL by irrigation diversions and infiltration losses along the river. When flow in the Big Lost River reaches the INEEL, it is either diverted at the INEEL diversion dam to the spreading areas (a series of four natural depressions shown on Figure B-4) or flows northward across the INEEL in a natural gravel fill. Twenty-nine kilometers (18 mi) northeast of the INEEL diversion dam, at the Big Lost River sinks, the main channel branches into several channels and then terminates in a series of four shallow playas that are connected by branching channels (Figure B-15). There are no recreational or human consumptive uses of this surface water.

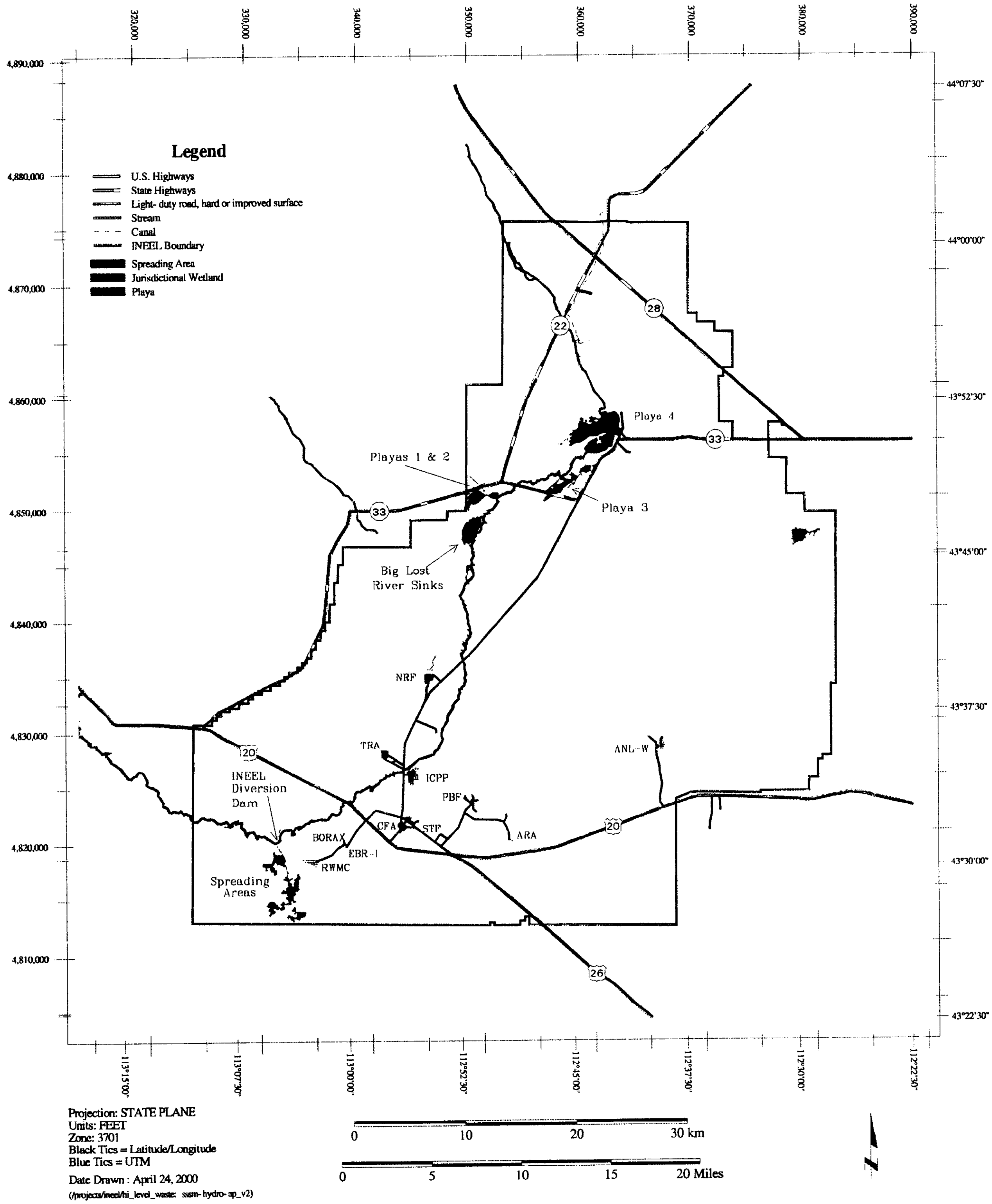


**Figure B-15.** Surface water features on the INEEL.

All flow of the Big Lost River that enters onto the INEEL, except for evaporation losses, is recharged to the subsurface. Groundwater recharge from the Big Lost River can be very pronounced in the Snake River Plain Aquifer and in perched groundwater. Water levels in the aquifer have risen over 10 feet in response to surface water infiltration from the Big Lost River (Pittman et al. 1988). In a study by Bennett (1990), infiltration losses from the Big Lost River channel were about 10% of the total flow volume between the INEEL diversion dam and INTEC gauging stations.

The need for flood control on the INEEL was first recognized in the early 1950s when downstream facilities (TRA and the INTEC) were threatened by localized flooding because of ice jams in the Big Lost River. The INEEL diversion dam was constructed in 1958 to divert high runoff flows from downstream INEEL facilities (Figure B-15). The diversion dam consists of a small earthen diversion dam and head gate that diverts water from the main channel, through a connecting channel, and into the spreading areas (Figure B-15). During the winter months, most of the flow in the river is diverted to the spreading areas to avoid accumulation of ice downstream in the main channel, which reduces the possibility of flooding at downstream INEEL facilities. Gates placed on two large, corrugated steel culverts, 1.8 m (6 ft) in diameter, control flow downstream toward the INEEL facilities. The gates can be closed to divert all flows into the spreading areas. When the gates are fully opened, the maximum flow through the diversion dam downstream toward the CFA is 26 $m^3/s$ (900 cfs) (Lamke 1969). Flow in the diversion channel to the spreading areas is uncontrolled at discharges that exceed the capacity of the culverts. The diversion channel is capable of carrying 204 $m^3/s$ (7,200 cfs) from the Big Lost River channel into the spreading areas. Two low areas located southwest of the main channel are capable of carrying an additional 60 $m^3/s$ (2,100 cfs) for a combined diversion capacity of 263 $m^3/s$ (9,300 cfs) (Bennett 1986). The capacity of the spreading areas is 58,000 acre-ft at an elevation of 1539 m (5,050 ft) (McKinney 1985). Flow from the Big Lost River has not been sufficient to exceed the capacity of the spreading areas and cause flow southwest off the INEEL, into adjacent low areas.

Birch Creek originates from springs below Gilmore Summit in the Beaverhead Mountains and flows in a southeasterly direction onto the Snake River Plain (Figure B-4). The water in the creek is diverted north of the INEEL for irrigation and hydropower purposes. A gauging station for Birch Creek located about 25 km (15 mi) northwest of the INEEL boundary indicates perennial flows of approximately 1 $m^3$ (40 cfs) to 2 $m^3$ (80 cfs) (United States Geological Survey [USGS] National Water Information System, internet site). When the water is not used for irrigation, typically November through April, it flows to a man-made channel on the INEEL, 6.4 km (4 mi) north of Test Area North, and recharges the Snake River Plain Aquifer by infiltration.

The Little Lost River drains the slopes of the Lemhi and Lost River mountain ranges. Water in the Little Lost River is diverted for irrigation north of Howe and does not flow onto the INEEL. The Little Lost River is considered to have negligible potential for flooding on the INEEL (Kjelstrom and Berenbrock 1996).

## B-5.1 Big Lost River 100-Year Flood

The 100-year flood represents a flood with a recurrence interval (return period) of 100 years, the average interval of time within which a flood of a predicted magnitude is expected to be equaled or exceeded at least once. Several studies have presented estimates of the potential magnitude of the 100-year flood for the Big Lost River. The 100-year flood for the Big Lost River near Arco, a station 22.5 km (14 mi) upstream from the INEEL diversion dam, has an estimated magnitude of approximately 105 $m^3/s$ (3,700 cfs) to 125 $m^3/s$ (4,400 cfs) based on a log-Pearson Type III distribution of historical stream gaging records (Tullis and Koslow 1983; U.S. Army Corps of Engineers 1991; and Stone et al. 1992). Another study used a log-Pearson Type III distribution for a station upstream of Mackay Reservoir combined with a regional regression approach for 22 subbasins and estimated peak flow of

204 $m^3$/s (7,200 cfs) for the 200-year flood for the Big Lost River at the Arco station (Kjelstrom and Berenbrock 1996). This estimate is considered to be conservatively high. The highest recorded flow at the Arco station was 125 $m^3$/s (1,890 cfs) in July of 1967. A recent study using paleohydrologic data collected from several stream reaches along the Big Lost River below the Arco station, in combination with historical stream gage data from the Arco station and a Bayesian flood-frequency analysis, estimates a magnitude of 94 $m^3$/s (3,300 cfs) for the 100-year flood for the Big Lost River at the Arco station (Ostenna et al. 1999). This latest study, which combines historical streamflow data with paleohydrologic field study sites along the Big Lost River, provides the best estimate of the 100-year flood to date. Therefore, a reasonable estimate of the 100-year flood for the Big Lost River at the Arco station is considered to be 94 $m^3$/s (3,300 cfs).

### B-5.2 Big Lost River Floods with Return Periods Greater Than 100 Years

Ostenna et al. (1999) performed a Bayesian flood-frequency analysis that indicates peak flows on the Big Lost River with return periods of 500, 1,000, and 10,000 years are 113 $m^3$/s (4,000 cfs), 125 $m^3$/s (4,400 cfs), and 150 $m^3$/s (5,300 cfs), respectively. These results suggest that exceedance of the estimated maximum capacity of the INEEL diversion dam of 263 $m^3$/s 9300 cfs (Bennett 1986) has an extrapolated annual exceedance probability smaller than 0.00001 (or greater than 100,000 year return period). Assuming a safe-holding capacity of 142 $m^3$/s (5,000 cfs) for the INEEL diversion dam, the annual exceedance probability is 0.0002 (or a 5,000 year return period).

## B-6. SUBSURFACE HYDROLOGY

This section describes the vadose zone, perched water bodies, and the groundwater at the INEEL.

### B-6.1 Vadose Zone

The vadose zone is the region of the subsurface that extends from land surface to the water table. It is a particularly important component of the INEEL hydrologic system. The thick vadose zone affords protection to groundwater by acting as a buffer or filter thus slowing or preventing many contaminants from reaching the SRPA. Water is the primary mechanism for most chemical transport in the vadose zone, although vapor transport can be significant for volatile constituents. Water movement is generally moving under unsaturated-steady state conditions, although episodic fluxes occur during the spring snowmelt or if the site is near the Big Lost River or an infiltration pond. These pulses of water may drive water and contaminants meters in a matter of days or weeks. Information on sources of water, geology, and topography can be used to determine areas that have a higher probability of recharge and subsequent movement of contaminants.

The vadose zone at the INEEL ranges from 61 m (200 ft) in the northern portion of the Site to more than 274 m (900 ft) in the southern portion. The Snake River Plain is characterized by a layer of surface sediments of variable thickness underlain by a thick sequence of basalt flows interfingered with sediments. Topography is generally gentle with subtle variations in elevation. These subtle variations may allow localized recharge during spring snow melt or rainfall events.

Collection of water at the surface is the primary factor controlling recharge to the subsurface. Concentrating water in streams, infiltration ponds, or surface ponding can allow standing water to infiltrate into openings in the sediment or basalt. This moisture can move rapidly below the depth of evapotranspiration where it will then continue to move under the force of gravity. Small precipitation events or diffuse sources of water will generally move at a slower rate through the sediments and may be removed by evapotranspiration. Coarse texture and disturbance of the surficial sediments can allow moisture to infiltrate more rapidly into the subsurface increasing the recharge rate if there are significant sources of water.

Sites with native plant growth, fine-grained sediments, and undisturbed original sediment stratification generally have relatively low moisture contents and water potential in the first 3 to 6 m (10 to 20 ft) below land surface. The plant growth root mass and natural stratification of geologic units slow water movement through the unsaturated zone. Sites where the native plant growth and original sediment stratification have been disturbed have generally higher moisture contents and water potential because there is little or no evapotranspiration and the disturbed sediments allow water to move more quickly through these materials.

Sediment grain size controls the infiltration rate of water moving from land surface to the subsurface. If the grain size is relatively large at land surface, such as from rip-rap, gravel or sand, there can be rapid migration of water into the subsurface. Depending on their position relative to land surface, finer-grained materials, such as clays, can reduce infiltration rates by several orders of magnitude. Additionally, sediment grain size controls the retention of water in surficial materials. Large-grained materials, such as rip-rap, gravel or sand, allow rapid infiltration, but have fairly low moisture contents because they do not retain much water within the large interstitial spaces between grains. Finer-grained sediments, such as loam or loess, tend to hold larger volumes of water due to the stronger capillary forces that occur at smaller pore sizes.

At the INEEL, vadose zone soils tend to be relatively dry during most of the year near land surface (<3 m) because of the relatively low annual precipitation, high potential evapotranspiration, and deep water table. At depths below 3 m, the moisture content approaches specific retention (the water content that remains following gravity drainage). Water potentials are in the range of -100 to -250 cm in both the sediment and basalt (Sisson and Hubbell 1999) below the 3-m depth. Most of the soils on the INEEL are well-drained; that is, water is removed from the soil readily, but not rapidly. These soils are typically medium textured. Soils that range from poorly drained (clays), to excessively drained (gravels) are found on the Site. The permeability of Site soils ranges from slow, 0.15 to 0.51 cm/hour (0.06 to 0.20 in./hour) to very rapid, more than 51 cm/hour (20 in./hour) with most soils in the 0.51 to 5 cm/hour (0.2 to 2.0 in./hour). Details about the above soil characteristics are provided by Olson, Jeppesen, and Lee (1995).

The hydraulic properties of the vadose zone (basalt layers and sedimentary interbeds) are site dependent. Studies of unsaturated hydraulic properties of sediments and basalt have been performed by various investigators for several sites (McElroy and Hubbell 1990; Bishop 1991; D. B. Stephens and Associates 1993; Knutson et al. 1990, 1992). The majority of the vadose zone characterization activities have been performed at the RWMC, TRA, and the CFA Landfill facilities. Hydraulic properties for various components of the vadose zone have been determined at specific locations and are summarized below.

Bishop (1991) and Knutson et al. (1990, 1992) measured hydraulic properties of vesicular basalt obtained at the RWMC. The mean horizontal and vertical saturated hydraulic conductivities were 8.42E-06 and 9.81E-05 cm/second (2.8E-07 and 3.2E-06 ft/second), respectively. The effective porosity was 23%. Moisture characteristic curves indicated that the moisture content was about 4% at -250 cm of water potential.

D. B. Stephens and Associates (1993) measured hydraulic properties of a shallow sedimentary interbed between CFA Landfills II and III. The hydraulic properties reflect the generally coarse nature of these sediments. However, considerable variation exists in these properties (e.g., the saturated hydraulic conductivity varies by more than three orders of magnitude at a range of 9.8E-06 to 4E-02 cm/second, and moisture retention at -15,000 cm water varies from 5.3 to 21.9% [$cm^3/cm^3$]). McCarthy and McElroy (1995) summarized hydraulic data from the surficial and interbed sediments at the Subsurface Disposal Area (SDA) and indicated that the sediments vary from clays to gravels. Surficial sediments at the SDA (Laney et al. 1988) consist of both areas with relatively high water contents (high water potential) and areas with low water contents (low water potential) that were related to drainage channels and surface ponding of water from snowmelt and runoff. Thus, site specific data are necessary to characterize the hydraulic properties of individual sites within the SDA.

The movement of water through thick sequences of basalt flows and sedimentary interbeds can be relatively rapid during periods of saturation. Morris et al. (1963) observed the rise of the water table at a depth of about 142 m (465 ft) in Well 5 about 15 to 20 days after the beginning of runoff from the rapid Spring thaw in 1962. The water table rose from 141 m (463 ft) to about 142 m (466 ft) below land surface. Barraclough et al. (1967) reported that the water level in Well 78 (62-m [203-ft] deep and 72 m [235 ft] from the Big Lost River) started to rise within four days after the water first flowed in the Big Lost River channel. Pittman et al. (1988) reported that water levels in some wells at the INEEL rose as much as 1.8 m (6 ft) or more in a few months following high flows in the Big Lost River. In a large field experiment, water infiltrating from a 6.6-acre circular pond advanced vertically through the basalt vadose zone at a rate of about 5 m/day (16.4 ft/day) (Wood and Norrell 1996). Water flow was confined within a vertical cylinder, the top of which was defined by the infiltration basin. A sedimentary interbed at the 54.5-m (180-ft) depth served as an impediment to the vertical water flow and directed the water laterally. These effects are in response to ponding of water at the surface and large volumes of water. Sisson and Hubbell (1999) monitored the movement of the wetting front through basalt from infiltration of snowmelt with minor ponding (less than 2 cm) at land surface; this front moved from land surface to a depth of 50 ft (15 m) in about three days.

Water can move rapidly through surficial sediments if the geologic media are coarse and there is sufficient moisture to wet the sediments. Hubbell (1995) and McElroy (1993) show water movement from land surface to a depth of 3.7 m in 11 days at the Subsurface Disposal Area. Moisture movement through sediments in the vadose zone at the INEEL under unsaturated conditions should be significantly slower than these observations suggest. The moisture movement depends on the amount of infiltrating water, the moisture content, and hydraulic conductivity of the materials. The same material features (e.g., open fractures and large pores within the basalt) that contribute to rapid flow during saturated conditions impede moisture movement under unsaturated conditions. Water moves in the unsaturated zone in response to soil water (matric), osmotic, and gravitational potentials. In fine-grained materials, capillary forces will draw moisture into pore spaces. In unsaturated, large-pore space materials, gravitational force may not be sufficient to displace the air occupying these spaces.

## B-6.2 Perched Water

Perched water bodies may form when a sufficient quantity of water moves downward through a higher conductivity zone and encounters a lower conductivity zone. Perched water zones have been identified at TRA, INTEC (formerly known as the Idaho Chemical Processing Plant), TAN, RWMC, and areas adjacent to the Big Lost River. Sources of water that can form or may have formed perched water within the vadose zone include past wastewater disposal to injection wells, percolation ponds, ditches, leaks in facility piping systems, surface ponding of water from snowmelt, and groundcover irrigation.

The presence of perched water can increase flux rates, form preferential flow paths, and allow for more dissolution of contaminants. Unsaturated hydraulic conductivity of porous materials is a function of moisture content; increasing moisture content corresponds with higher hydraulic conductivity. The relationship is nonlinear and thus small increases in water content can correspond to orders of magnitude increases in flux rates. As saturated conditions form, water can enter larger pores and fissures that were barriers to flow under unsaturated conditions. Typically, the large cooling fractures in the basalt will not transmit water until full saturation is attained. Once saturation is attained, water can enter the large opening and move large distances vertically or horizontally. This preferential flow may allow water to move in unpredictable directions laterally with water moving in nearly any direction. Perched water adjacent to the contaminants may allow dissolution of additional solute that then can be transported as the moisture moves into the underlying geologic media.

The geohydrologic characteristics of the unsaturated zone underlying these sites differ with respect to basalt and sediment lithology, stratigraphic unit thickness, sources of water, and physical orientation. The degree of saturation varies both horizontally and vertically. Though these differences exist, the features that control the formation of perched groundwater zones may be common to the sites. Despite numerous wells being drilled at various sites, it is frequently difficult to detect, monitor, and determine the perching mechanisms using conventional drilling and monitoring techniques. Tools and techniques to detect and monitor these perched water zones are only now becoming available.

At least four generalized lithologic features may contribute to perched groundwater formation. The sharply contrasting lithologic features of basalt flows and sedimentary interbeds provide mechanisms for the development of perched groundwater bodies in the unsaturated zones. First, the dense, unfractured interior of basalt flows may inhibit unsaturated groundwater movement and contribute to the formation of perched water zones within the overlying fractured basalt. Second, the vertical hydraulic conductivity of a sedimentary interbed may be lower than that of an overlying (fractured) basalt flow. Third, permeability alterations that occur in the baked zones between basalt flows may result in different hydraulic characteristics of the underlying flow, which would reduce vertical hydraulic conductivity. Fourth, sedimentary and chemical in-filling of the highly fractured upper contact surface of a basalt flow can reduce vertical hydraulic conductivity. The rate and volume of water being transported through the unsaturated zone, as well as the hydrogeologic characteristics of the media, determine if perched water is formed.

At TRA, a vertical sequence of discontinuous perched water zones formed in unsaturated basalt flow groups and sedimentary interbeds have been observed. Thick sections of basalt and sedimentary interbeds are saturated near the TRA ponds. The perched water is over 20-m (60-ft) thick in places and extends laterally over 1,000 m in a southwest direction, counter to the prevalent groundwater flow direction. Geologic structures may influence the extent of these perched water zones and the vertical flow of water between zones. Anderson (1991) described a subsurface structural dome northeast of TRA. Domal deformation of basalts and sedimentary interbeds may limit the formation of perched groundwater zones to the northeast of the TRA ponds (Cecil et al. 1991).

The discharge of wastewater from two infiltration ponds at INTEC caused perched groundwater zones to form in the vicinity of the ponds. At least four perched groundwater zones have been identified beneath the infiltration ponds. These include a zone of saturation in the surficial alluvium and three separate zones in the underlying basalt and sedimentary interbeds. By 1986, perched groundwater zones had formed at USGS Well 51 at depth intervals from 9 to 31 m (30 to 104 ft), 40 to 54 m (134 to 178 ft), and 80 to 98 m (266 to 322 ft). A thin perched groundwater zone formed at the surface alluvium-basalt interface because the alluvium is relatively more permeable than the underlying basalt (Cecil et al. 1991).

Perched water at TAN occurs below the Technical Support Facility waste pond. The lateral extent of the perched water zone is defined by wells in the area. Only two wells in the area penetrate the perched water zone. The data from these wells suggest that the extent of the perched water is limited to beneath the wastewater pond. The perched water zone in this area lies at a depth of approximately 13.6 to 15.2 m (45 to 50 ft) at the first soil and basalt interface.

From 1976 to 1977, wet zones were identified in vadose zone wells at the RWMC (Barraclough et al. 1976; Hubbell 1990; Cecil et al. 1991). Perched groundwater was identified intermittently in two zones above sedimentary interbeds at about 80–90 ft and 222 to 246 ft below land surface (Hubbell 1990). Drilling and monitoring data suggested that the perched water was discontinuous at this site. Water level data from USGS 92, in the center of the SDA, suggested that water recharged to the spreading areas about 1,300 m (4,400 ft) might be impacting this well (Hubbell 1990). Recently, the USGS placed tracers in the Spreading Area west of the RWMC (Orr, Cecil, and Knobel 1991). Tracer was detected in USGS Well 92 in the center of the RWMC above the 73-m (240-ft) interbed about 90 days following tracer introduction. This suggests a water movement of over 1,300 m (4,300 ft) laterally and 70 m (230 ft) vertically over three months. Wells at the Large Scale Infiltration Test site, 1.6 km (1 mi) east of the spreading areas, also had tracer in them following the tracer introduction. This suggests that the formation of perched water may be widespread near the spreading areas.

## B-6.3 Snake River Plain Aquifer

The SRPA is approximately 320-km (200-mi) long and varies in width from 48 to 97 km (30 to 60 mi). The aquifer extends in Idaho from near Ashton to the Thousand Springs area near Twin Falls and is bounded by the relatively less permeable rocks of the bordering mountains (Figure B-4). The INEEL is located in the northwestern section of the aquifer and overlies about nine percent of the SRPA, covering about 24,600 $km^2$ (9,600 $mi^2$). The SRPA is one of the most productive aquifers in the United States (Lindholm 1981). The aquifer itself may contain more than 1E+12 $m^3$ (1E+09 acre-ft) of water (Barraclough, Lewis, and Jensen 1981) and consists of thick sequences of saturated basalt and sedimentary interbeds filling a large, arcuate, structural basin. The Environmental Protection Agency has designated the SRPA as a "sole source aquifer" under the Safe Drinking Act (56 Federal Register 50634). The SRPA serves as the only drinking water supply source for much of southeastern Idaho.

The structure of individual basalt flows largely governs the transmission of water through the Snake River Plain Aquifer. The upper vesicular element of a flow, with its parting, fissures, and broken basalt, combines with the fractured, often rubbly substratum of the overlying flow to form a highly transmissive interflow zone. The predominantly horizontal movement of water through hydraulically connected interflow zones generally characterizes groundwater flow in the SRPA. The vertical movement of water is generally limited because it is restricted to vertical fractures and joints. The dense interior elements of basalt flows impede the vertical transport of water. Further contributing to the reduction of vertical flow is the presence of sedimentary interbeds. The transmissivity of interbeds is at least an order of magnitude lower than the transmissivity of basalt (Whitehead 1992).

The basalt is comprised of a low permeability, high porosity matrix surrounded by a lattice of fractures. Some of these fractures have extremely high permeability, with flow approximating pipe flow. On a small scale (up to hundreds of feet), the hydraulic properties of the basalt are extremely nonuniform and highly variable, and the direction of groundwater movement at any given point within is correspondingly variable and unpredictable. However, on a larger scale, the aquifer may approximate a nearly homogeneous system. Regional flow direction within the aquifer is principally to the south and southwest toward discharge points along the Snake River in the Thousand Springs, Idaho, region (Figure B-16).

Groundwater levels near the Big Lost River are influenced by recharge from the Big Lost River when it flows onto the INEEL. Infiltration from the Little Lost River and Birch Creek to the north and west also add some recharge to the aquifer while infiltration from direct precipitation on the INEEL probably contributes only minor recharge. Withdrawals by pumping at the INEEL are small in comparison to the total volume of water stored in the aquifer and do not affect water levels significantly. Groundwater contours based on 1995 water table data are shown in Figure B-16.

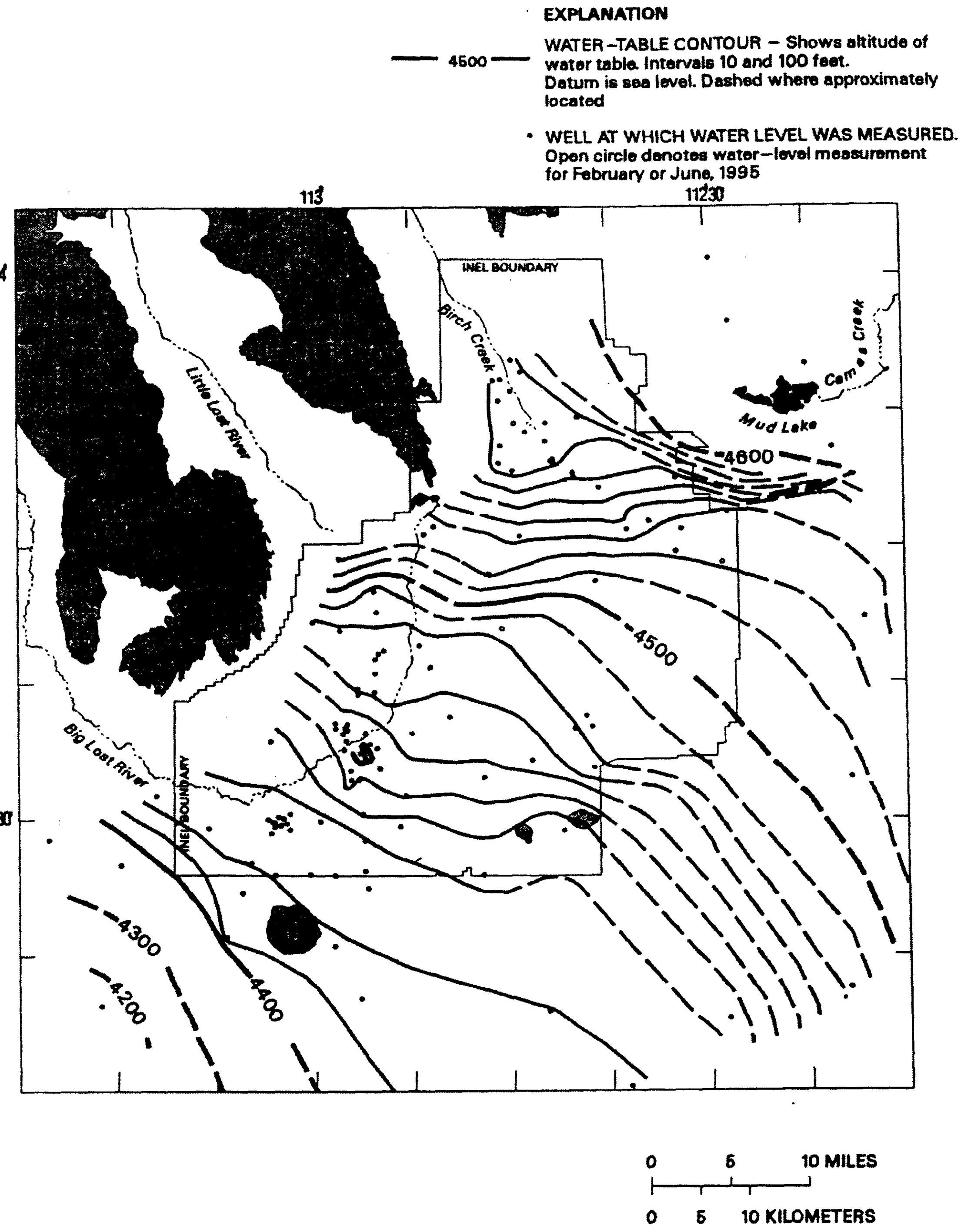


**Figure B-16**. Altitude of the water table for the Snake River Plain Aquifer in the vicinity of the INEEL, March–May 1995.

The SRPA generally behaves as an unconfined aquifer, although in places and at a local scale it behaves as though it were confined (Nace et al. 1959). Unconfined aquifers have their upper surface free to rise and decline. Since the basalt has dual porosity with the larger portion of the mass having a low permeability and only the fractures and fractured interflow zones having very high permeability, it acts like a gravel aquifer with immense grain size (tens of meters across). Drilling at any location may penetrate a portion of the aquifer that has no confining bed, but drilling is more likely to penetrate the rock mass and the basalt will act as a confining bed over the scale of a few meters to tens of meters.

Transmissivity determined from wells on the INEEL ranges from 372 to 2.23E+05 $m^2$/day (4,000 to 2.4E+06 $ft^2$/day) (Robertson, Schoen, and Barraclough 1974). These transmissivities are calculated from aquifer stress tests, which assumes that water is obtained from the entire saturated thickness. In actuality, most of the water flow may come from intervals a few meters thick. The lower transmissivities were reported from wells near TAN and the highest values were from wells near TRA. A more recent evaluation by Ackerman (1991) showed that typical values for transmissivity at the INEEL range from 0.1 to 71,000 $m^2$/day (1.1 to 760,000 $ft^2$/day). Storage coefficients calculated by Robertson, Schoen, and Barraclough (1974) ranged from 0.01 to 0.06. These storage coefficients suggest low porosities in the aquifer matrix. Further, they show that there are few areas of high permeability compared to the effective porosity determined in the laboratory of about 23% (Knutsen et al. 1990). The aquifer matrix properties control the groundwater flow velocities and, in part, the direction of flow.

Average groundwater flow velocities for basalt are estimated in the range of about 1.5 to 9 m/day (5 to 30 ft/day), assuming a uniformly distributed porosity of up to 5%, a saturated thickness of 305 m (1,000 ft), and an average hydraulic gradient of 0.1 m/km (5 ft/mi) (Nace et al. 1959). However, it is known that porosity is not uniformly distributed; computations using average transmissivity values and the porosities of highly permeable basalt zones yielded velocities up to 91 m/day (300 ft/day) (Nace et al. 1959).

Tritium from INTEC waste has been used extensively in tracing groundwater flow velocities and directions (Morris and Teasdale 1964; Barraclough et al. 1967). Peaks of high tritium discharge to the INTEC injection well (CPP-03) have been particularly useful in determining the local flow characteristic in the SRPA. One of the most studied "peak" discharges of tritium occurred in December 1961 because it was preceded and followed by relatively long periods of low tritium discharge. Groundwater flow velocities determined from the tritium peak ranged from 7.6 m/day (25 ft/day) measured over a distance of 215 m (705 ft) to 3.1 m/day (10 ft/day) measured over a distance of 3,170 m (10,400 ft). Holdren et al. (1999) summarize data indicating that regions of the INEEL may have large scale preferential flow paths controlled by geologic features of the subsurface. Local groundwater flow directions are affected by the local recharge, variations in hydraulic conductivity, local pumping, and possibly vertical hydraulic gradients, making it difficult to monitor these flow directions.

The presence of fine-grained, clayey interbed deposits, with hydraulic conductivities, typically three to five orders of magnitude lower than that of the surrounding fractured basalt, also will impede and influence the vertical and horizontal movement of groundwater. Fracture joints in the central portion of the lava flow, typically massive basalt, are usually vertical in orientation and are believed to serve as the primary means for vertical groundwater movement. In the central portion of basalt flows, a paucity of fractures leads to little vertical or horizontal movement of groundwater.

Beneath the INEEL, depth to the aquifer varies from about 60 m (200 ft) in the northern portion of the site to more than 280 m (900 ft) at the southeastern portion of the site. The groundwater beneath the INEEL generally flows south and southwest. The average hydraulic gradient of the 1995 water table surface is approximately 0.75 m/km (4 ft/mi) and ranges from 0.2 to 2.8 m/km (1 to 15 ft/mi). Data suggest that the volume of groundwater flowing beneath the INEEL at its widest point is about 60 $m^3$/second (2,000 $ft^3$/second) (Mundorff, Crosthwaite, and Kilburn 1964).

Groundwater in the Snake River Plain Aquifer has the large potential for water resource development for almost any purpose. The high transmissivity and fast flow rates make it ideal for large-scale water usage. The fractured nature of the aquifer, great depths to the aquifer, high transmissivity and fast flow rates make it difficult to detect low concentrations of contaminants and determine flow directions over small areas.

# B-7. CULTURAL RESOURCES

In response to federal environmental legislation, investigations of INEEL cultural resources were initiated in the late 1960s. Several categories of cultural resources have been identified within the INEEL facility boundaries, including archaeological sites, Native American traditional cultural sites, and contemporary historic sites. The *INEEL Management Plan for Cultural Resources* (Miller 1995) contains a comprehensive history of cultural resource management activities at the INEEL, descriptions of the many cultural resources identified to date on the INEEL, and a synopsis of the legal mandates for cultural resource management in the United States.

## B-7.1 INEEL Cultural Resources

Over the past two decades, detailed cultural resource inventories have been assembled for some parts of the INEEL. Most of these survey efforts have focused on areas within and around major operating facilities and proposed future construction areas. Detailed inventories of prehistoric and historic archaeological sites have been assembled through these efforts. Far less is known about the distribution of traditional Native American cultural resources. However, this is beginning to change as consultation with the Shoshone-Bannock Tribes increases and tribal people become more actively involved in the process of resource inventory and protection. Inventories of contemporary historic resources are also ongoing. Efforts to date have also focused on major operating facilities, but attention has been limited to buildings. Other structures within the built environment are still under investigation.

### B-7.1.1 Archaeological Sites

As of January 1999 (Pace 2000), approximately 7.5 % of the INEEL (42,962 acres) had been systematically surveyed for archaeological resources and 1,884 localities had been identified. Approximately 95% of the resources within the current inventory are campsites, lithic scatters, and rock features created by Native American hunter-gatherers during the prehistoric period (150 – 12,000 years ago). A preliminary predictive model suggests that there may be as many as 75,000 additional resources of these types as yet undiscovered within the boundaries of the INEEL (Ringe 1995). Also represented in the inventory of 1,884 resources are archaeological localities that reflect more recent activities including homesteads, old canals and canal construction camps, emigrant trails, stage stops, and railroad sidings. Because the INEEL area has seen only limited public access for the past 50 years, many of these archaeological sites, prehistoric and historic alike, are remarkably well preserved.

### B-7.1.2 Native American Cultural Sites

The prehistoric archaeological record does not make clear when the ancestors of the Shoshone and Bannock peoples arrived in southeastern Idaho. However, the Shoshone-Bannock Tribes believe that native people were created on the North American continent and, therefore, regard all prehistoric resources at the INEEL as ancestral and important to their culture. Ongoing consultation with contemporary Shoshone-Bannock tribal members has also demonstrated that a variety of natural landforms and features in the INEEL region are of sacred and traditional importance. Shoshone and Bannock people have a very unique and special relationship with their environment. Social, cultural, and spiritual values, beliefs and philosophies are tied to their relationships with the natural world and the survival of their culture is intimately intertwined with the health of the terrestrial and aquatic resources that have always supported them. Direct involvement of tribal people has been essential in any efforts to identify these sensitive resources.

### B-7.1.3 Contemporary Historic Sites

Recent buildings, structures, and objects that have made significant contributions to the broad patterns of American history through their association with World War II, the Cold War, and important advances in nuclear science and technology are also numerous on the INEEL. Comprehensive inventories of these important contemporary cultural resources have just begun. To date, 217 buildings have been flagged for additional historical research (Arrowrock Group 1997). Some of these resources will be determined eligible for listing on the National Register of Historic Places for the important scientific achievements that they represent. Experimental Breeder Reactor I, the first reactor in the world to produce useable amounts of electricity, has already been recognized in this manner and is designated as a National Historic Landmark.

## B-7.2 WAG 6 Cultural Resources

Several small archaeological surveys have been conducted within WAG 6. Areas that have been examined include the power line leading into EBR-I from substations to the northeast, a 40 meter-wide corridor surrounding the exterior facility fence at EBR-I, an 850 ft-long waterline extending from a deep well northwest of EBR-I into the facility, an 80 meter-wide corridor around the inactive Boiling Water Reactor Experiment (BORAX) facility area, and a 1,500 ft-long ditch extending northwest from the inactive BORAX facility area. Only two prehistoric archaeological resources, both isolated finds of fragmentary chipped stone tools, have been identified in the surveyed areas. However, large prehistoric archaeological sites have been identified a short distance from the EBR-I/BORAX complex, indicating that the area may contain additional resources.

The archaeological materials identified within WAG 6 leave no doubt that Native American populations utilized the area during the past. Consultation to determine the importance of the area to contemporary members of the Shoshone-Bannock Tribes is ongoing.

Many important contemporary historic cultural resources are located within WAG 6 (Braun 2000). EBR-I was the first INEEL reactor to become operational and shortly after start-up, it became the first reactor in the world to produce usable amounts of electricity. Subsequent experiments proved the feasibility of the "breeder" concept when the reactor produced as much fissionable fuel as it used in 1953, addressing a nation-wide shortage of reactor fuels. For these and many other historic world "firsts," President Lyndon Johnson designated EBR-I a National Historic Landmark in 1966, a scant 15 years after its initial start-up. In 1955, more international attention was directed toward Idaho when the BORAX III reactor became the first in the world to light a city. This and other BORAX tests demonstrated the feasibility of nuclear power plants to provide commercial electric power and also improved the technology and overall safety of boiling water reactors. All of the BORAX facilities were demolished before a final determination of National Register eligibility. The massive engines on display near the EBR-I reactor building also have an important story to tell about INEEL ingenuity and scientific achievement. These giant prototype turbojet engines proved the feasibility of using nuclear energy to operate aircraft. Though the technology was never actually installed in any Air Force jets, the project did result in major contributions in the study of reactor fuels and materials as well as radiation shielding.

Documentation is currently being assembled to nominate these structures to the National Register of Historic Places.

## B-7.3 WAG 10 Cultural Resources

Cultural resources within WAG 10 are numerous and variable as a result of the wide geographic distribution of the designation and the undisturbed areas included within it. Archaeological surveys have been conducted at the Army Reentry Vehicle Facility Site (ARVFS), the Experimental Field Station/Dairy Farm, the Security Training Facility (STF)/Experimental Organic-Cooled Reactor (EOCR)/Organic-Moderated Reactor Experiment (OMRE) facility, the Zero Power Physics Reactor (ZPPR) facility, the Liquid Corrosive Chemical Disposal Area (LCCDA), and within all 29 of the identified ordnance locations. In nearly every instance, archaeological resources were identified. Multitudes of archaeological resources are also known to occur within the site-wide area. Native American resources are numerous as well, though there is currently no systematic inventory of them. Finally, a few historic buildings and structures within WAG 10 are potentially eligible for nomination to the National Register.

In the vicinity of ARVFS, no archaeological resources have been recorded during surveys of the access road and facility perimeter (10 acres). Archaeological sites are known from other nearby survey projects though and expanded survey coverage near ARVFS may result in the identification of new resources. Consultation with the Tribes will determine if any Native American cultural resources are associated with ARVFS. From a historic standpoint, ARVFS is evaluated as eligible for nomination to the National Register. Historic American Engineering Record documentation of the facility, now demolished, is preserved in the U.S. Library of Congress.

Archaeological survey coverage in the vicinity of the Dairy Farm/Experimental Field Station is also rather scanty and this may explain the lack of archaeological resources known for the facility. Approximately 20 acres within and immediately adjacent to the fenced facility perimeter have been examined, but no archaeological sites have been documented. Again however, surveys in nearby areas have revealed significant archaeological sites. These resources and others yet unidentified may be of importance to the Shoshone-Bannock Tribes. The Dairy Farm, itself, may also be eligible for nomination to the National Register because it has filled several unique roles in the development of the INEEL.

Many archaeological surveys have been conducted in the vicinity of STF/EOCR/OMRE and many archaeological sites have been identified there. For example, an examination of a 70-acre area immediately to the southwest of the facility resulted in the recording of seven isolated prehistoric artifacts and two denser scatters of artifacts designated as archaeological sites. A similarly high density of prehistoric archaeological resources was observed to the west of the facility during a survey of more than 900 acres. To date, the northern and eastern sides of the facility have yielded no evidence of prehistoric or early historic use, although surveys have only been conducted within a 100 meter-wide zone surrounding the built environment. Ongoing consultation with the Shoshone-Bannock Tribes should verify that the high archaeological sensitivity of the STF/EOCR/OMRE area mirrors an equally high incidence of Native American resources and sensitivities. Although the STF/EOCR/OMRE facility has been demolished, it is still considered to be eligible for nomination to the National Register. Surviving records should be consulted to assemble a Historic American Engineering Record documentation package for the facility in compliance with recommendations from the Idaho State Historic Preservation Office.

Large-scale archaeological surveys encompassing nearly 800 acres around Argonne National Laboratory–West have resulted in the documentation of 31 archaeological sites from the prehistoric time period and three representative of more recent historic activities. However, none of these identified sites are located in the vicinity of the ZPPR pit. This area may contain Native American resources though.

The pit, itself, is not likely to be eligible for nomination to the National Register, but the ZPPR experiments with which it is associated probably are eligible.

No archaeological sites have been identified during surveys of the LCCDA area. However, this may be due to the small size of the surveyed plots, for many archaeological sites have been found during surveys in the surrounding area. At this time, the nature and extent of Native American cultural resources within the LCCDA area are unknown. The area is not eligible for nomination to the National Register.

Archaeological surveys have preceded many of the ordnance removal actions within WAG 10 and many archaeological sites have been recorded. For example, at the Naval Ordnance Disposal Area, 20 prehistoric archaeological sites have been identified within a 112-acre survey area, the NOAA area has yielded five sensitive archaeological resources in a 33-acre survey area, a 13-acre survey area around Fire Station II yielded three archaeological sites, 19 archaeological sites were identified beneath the Anaconda Powerline, eight archaeological sites were identified in a 52-acre portion of the Railcar Explosion area, and nine isolated artifact locations were identified in a 120-acre portion of the Twin Buttes Bombing Range. Other ordnance locations have yielded smaller numbers of archaeological resources such as the Landmine and Fuze Burn area where one extensive historic archaeological site has been identified and the area east of TRA where one isolated prehistoric artifact was observed. A few ordnance locations have revealed no archaeological sites during intensive surveys. This includes the craters East of INTEC and the Mass Detonation Area. All of the identified prehistoric archaeological sites in ordnance locations within WAG 10 are certain to be of importance to the Shoshone-Bannock Tribes and the various areas could also contain other types of sensitive Native American cultural resources. National Register-eligible contemporary historic sites are also present in some ordnance locations. The following sites in particular exhibit this potential: the Naval Ordnance Test Facility, the CFA-633 Naval Firing Site, the Old Military Structures, miscellaneous structures at the Mass Detonation Area, the Igloo-type structures, and Juniper Mine. All should be further evaluated to establish their historic importance.

# B-8. FLORA AND FAUNA

The following sections describes the flora classes and fauna types as well as the threatened and endangered species generally located at the INEEL and specifically found in the vicinity of WAGs 6 and 10.

## B-8.1 FLORA

Fifteen cover classes of vegetation have been identified using satellite image analysis (Kramber et al. 1992). The classes are Juniper woodlands, Steppe, Sagebrush-Steppe off-lava, Sagebrush-Steppe on-lava, Sagebrush/Winterfat, Sagebrush-Rabbitbrush, Sage/Low-sage/Rabbitbrush off-lava, Salt Desert Shrub, Steppe-Small Sagebrush, Grassland, Basin Wildrye, Wetlands, Old field-disturbed seedings, Lava, and Playa-bareground/gravel-borrow pits. The 15 classes have been combined into ten broader cover classes. These broad classes do not represent homogeneous community types. Each consists of a variety of intergrading communities that share some dominant species and have similar physiognomies; they tend to be more similar to each other than to communities represented by other vegetation classes. Figure B-17 shows these vegetation classes. Much of the information presented in these sections has been taken and updated from the *Environmental Resource Document for the INEL* (Irving 1993), *Guidance Manual for Conducting Screening Level Ecological Risk Assessment at the INEL* (VanHorn, Hampton, and Morris 1995), and *Plant Communities, Ethnoecology, and Flora of the Idaho National Engineering Laboratory* (Anderson et al. 1996a).

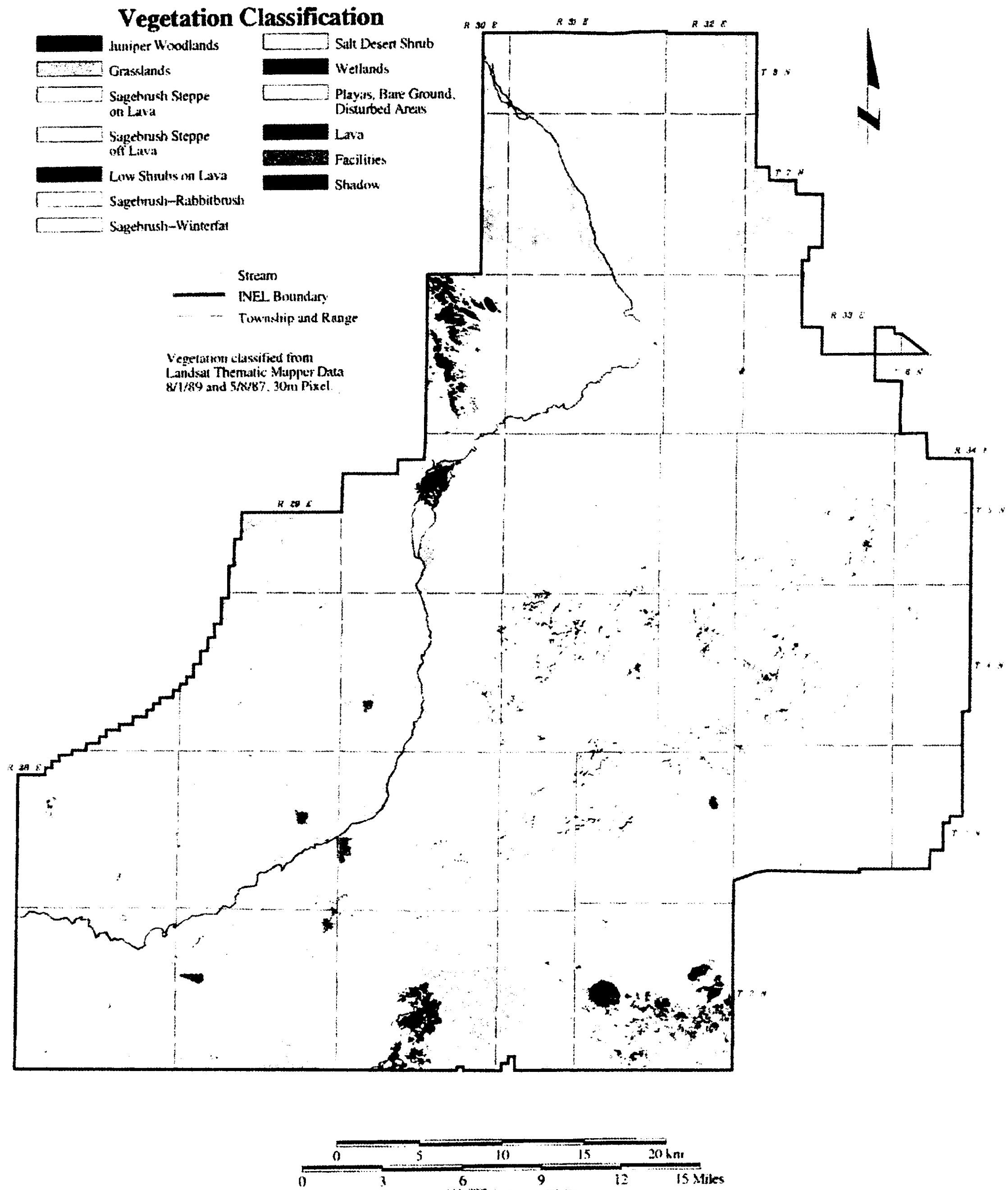


**Figure B-17.** Vegetation classes on the INEEL.